



Lunar Quest Program

# The Lunar Quest Program and the International Lunar Network (ILN)

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Briefing to MSFC OSAC 1/30/09

# Lunar & planetary science at MSFC



Lunar Quest Program

## Lunar activities within NASA

OSEWG Surface Systems  
Research & Analysis  
NASA Lunar Science Institute

## Lunar activities at MSFC

**Lunar Quest Program**  
Lunar Precursor Robotics Program  
Lunar Environments  
Lunar Soil Simulants Ares/Altair

## Lunar & planetary science group

Dr. Barbara Cohen, ILN Project Scientist  
Dr. Sarah Noble, LMMP project scientist  
Dr. Jennifer Edmunson (postdoc)

Core capability in planetary  
surface missions &  
instruments

Core capability in  
planetary sample analysis



# Lunar Quest Program



Lunar Quest Program

- ✧ The Lunar Quest Program is a Science-based program with the following goals:
  - Fly small/medium science missions to accomplish key science goals
  - Build a strong lunar science community
  - Provide opportunities to demonstrate new technologies
  - Where possible, help ESMD and SOMG goals and enhance presence of science in the implementation of the VSE
- ✧ The Lunar Quest Program will be guided by recommendations from community reports, such as
  - Planetary Decadal Survey  
[http://www.nap.edu/catalog.php?record\\_id=10432](http://www.nap.edu/catalog.php?record_id=10432)
  - Scientific Context for the Exploration of the Moon  
[http://books.nap.edu/openbook.php?record\\_id=11954](http://books.nap.edu/openbook.php?record_id=11954)
- ✧ Project management will be assigned
- ✧ Science and generally, science instruments will be competed

# Lunar Quest Missions



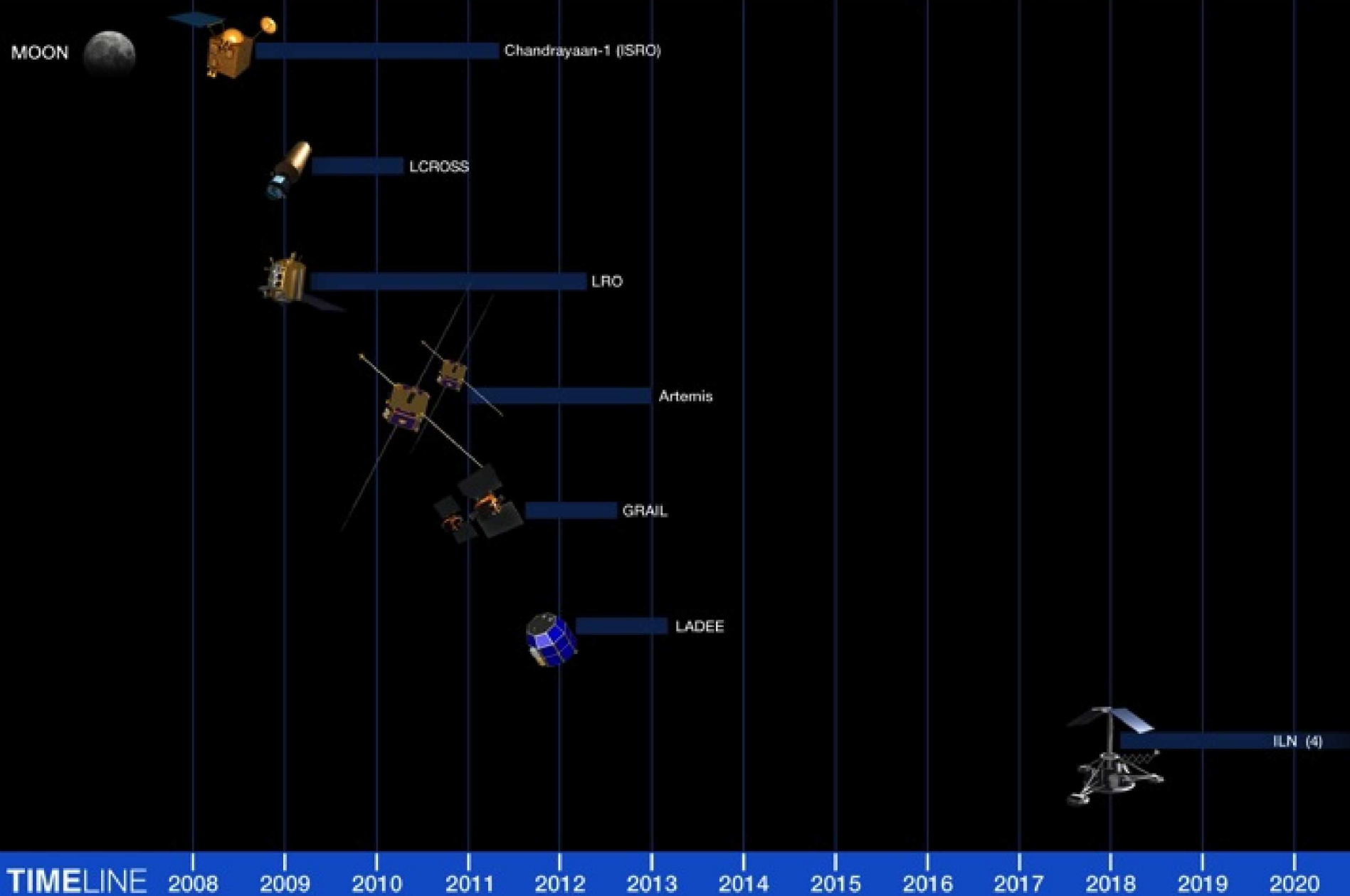
Lunar Quest Program

- ✧ NASA Lunar Science flight projects
  - Robotic missions to accomplish key scientific objectives
  - Provide useful data to ESMD and SOMD for returning humans to the Moon
- ✧ Mission 1: Lunar Reconnaissance Orbiter (**LRO**)
- ✧ Mission 2: Lunar Atmosphere and Dust Environment Explorer (**LADEE**)
- ✧ Mission 3: US landers as part of the International Lunar Network (**ILN**)

*These projects provide a **robotic lunar flight program** for the next decade, complement SMD's lunar R&A initiatives to **build a robust lunar science community**, and increase **international participation** in NASA's exploration plans*



# Lunar Mission timeline

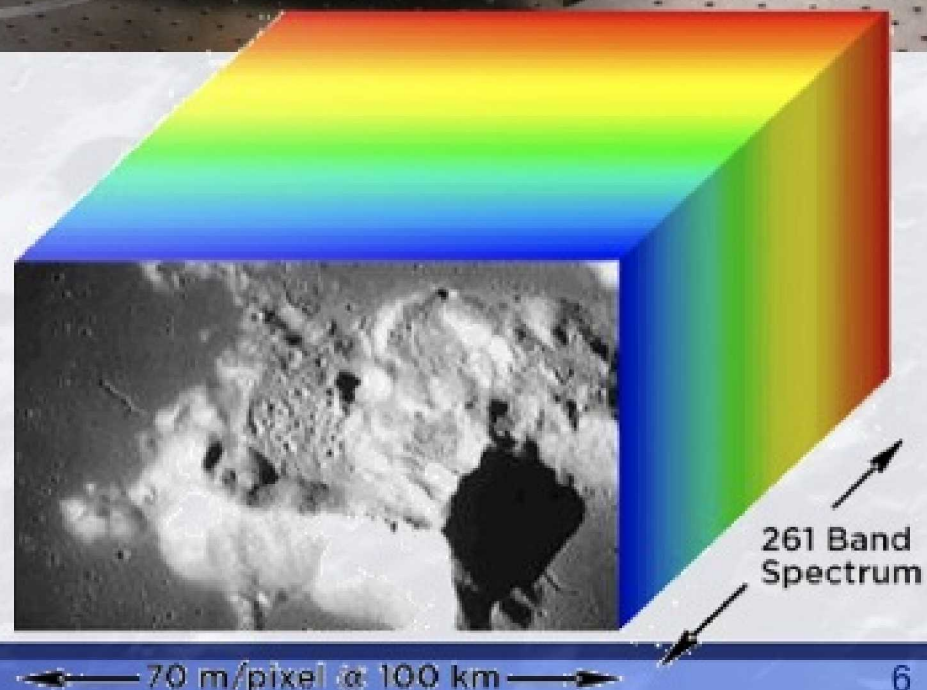


# Moon Mineralogy Mapper (M3) (2008)



Lunar Quest Program

- ❖ Mission of Opportunity under the Discovery Program - PI Carle Pieters, Brown University
- ❖ Mapping spectrometer on India's Chandrayaan-1 orbiter (launched Fall 2008)
- ❖ **M3 Objectives:**
  - Produce a global mineralogical map of the lunar surface at 140m spatial and 40 nm spectral resolution
  - Investigate specific targets at high spatial and spectral resolution
  - Investigate the possibility of water ice at the lunar poles





# LRO (2009)

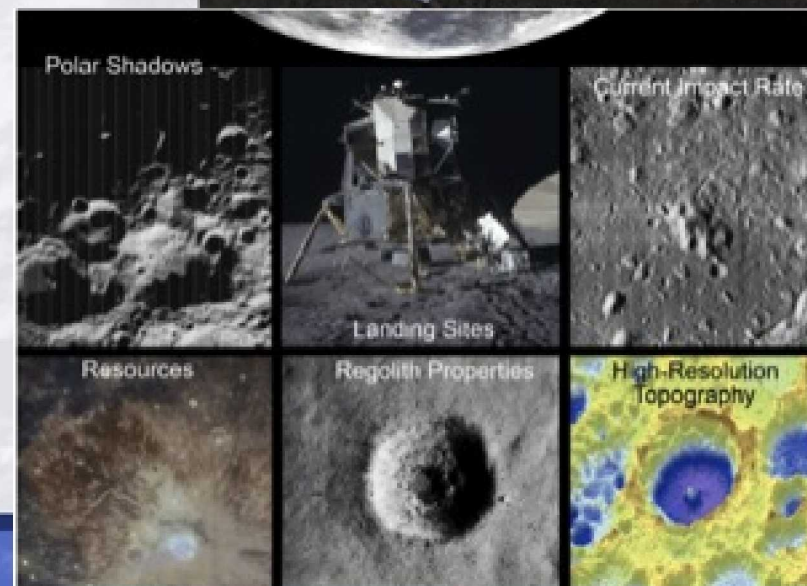


Lunar Quest Program

- ❖ Lunar Reconnaissance Orbiter (LRO) – first step back to the Moon in the Vision for Space Exploration. Focus is on datasets to help plan future human activities. Goddard project, managed under LPRP at MSFC

- ❖ **LRO Objectives:**

- Characterize the lunar radiation environment, biological impacts, & potential mitigations. Develop a high res global, 3D geodetic topographical grid of the Moon for selecting future landing sites.
- Assess the resources & environments of the Moon's polar regions.
- High spatial resolution assessment of the Moon's surface addressing elemental composition, mineralogy, & regolith characteristics



# LCROSS (2009)

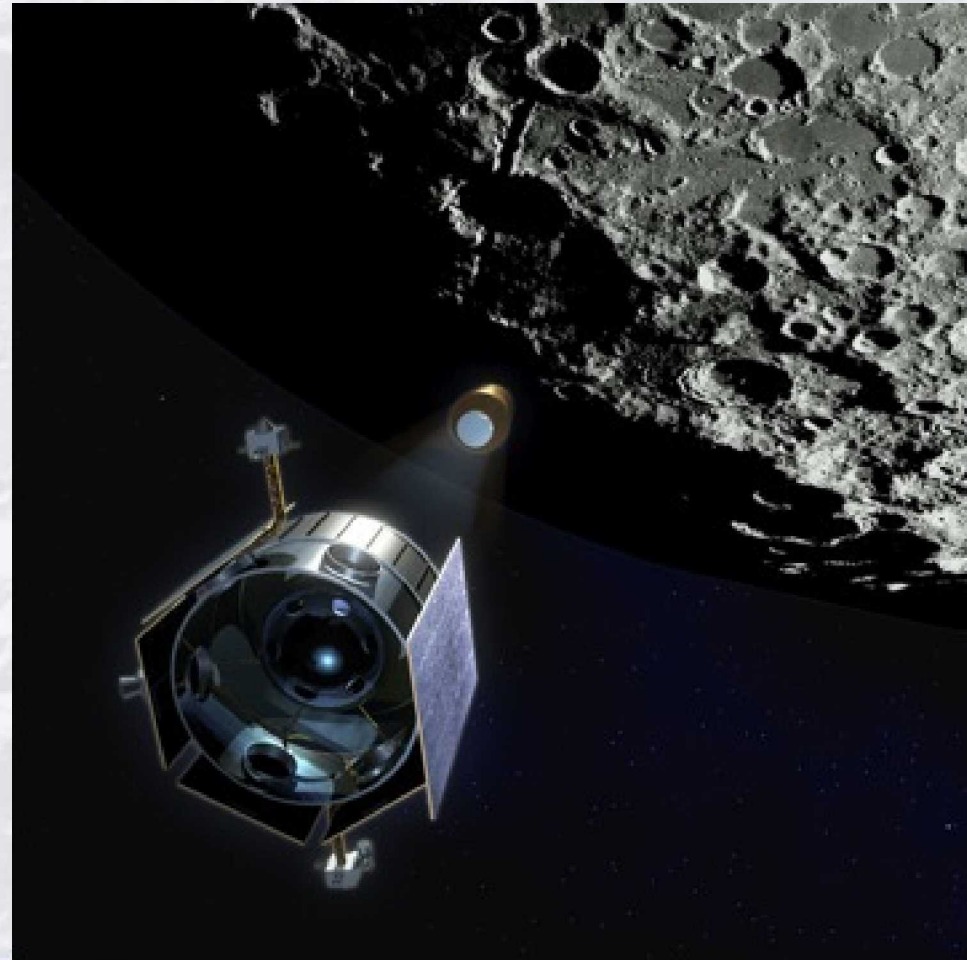


*Lunar Quest Program*

✧ Lunar Crater Observation & Sensing Satellite - secondary payload on LRO vehicle, Ames project under LPRP management at MSFC

✧ **LCROSS Objectives:**

- Confirm the presence or absence of water ice in a permanently shadowed crater at a lunar pole
- Create an ejecta plume and analyze it for the presence of water (ice and vapor), hydrocarbons and hydrated materials
- Provide technologies and modular, reconfigurable subsystems that can be used to support future mission architectures



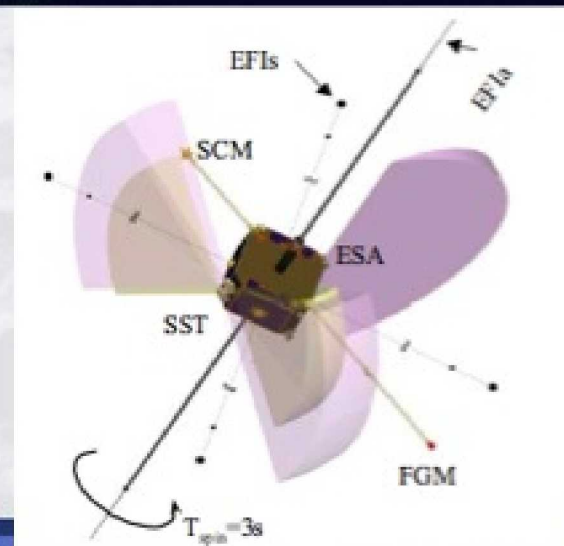
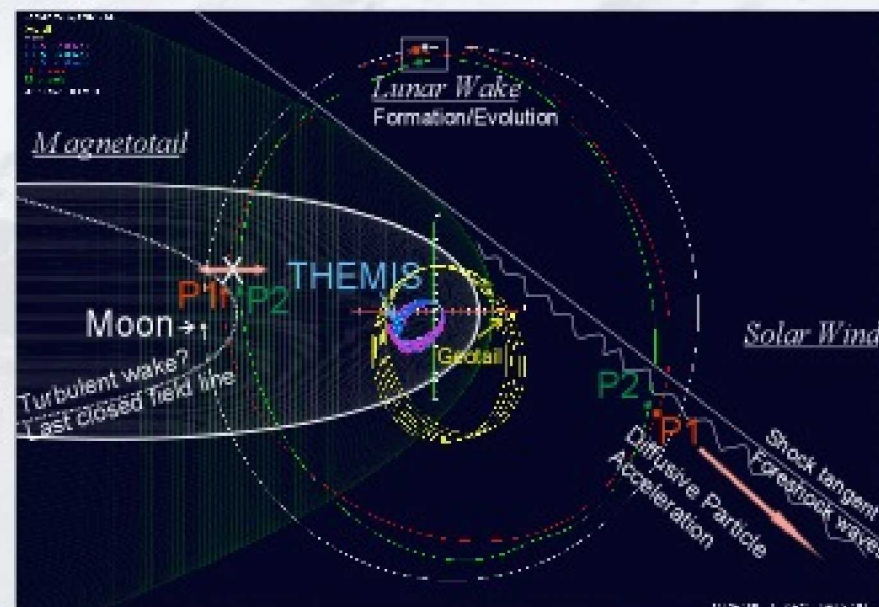


# ARTEMIS (2010)



Lunar Quest Program

- ❖ ARTEMIS (Acceleration, Reconnection, Turbulence and Electrodynamics of Moon's Interaction with the Sun) moves two THEMIS (Heliophysics MIDEX mission) satellites into orbits around the Moon
- ❖ **ARTEMIS objectives:** Study the lunar space environment, solar wind, magnetotail and lunar wake using MIDEX particles and fields instrumentation.



# GRAIL (2011)



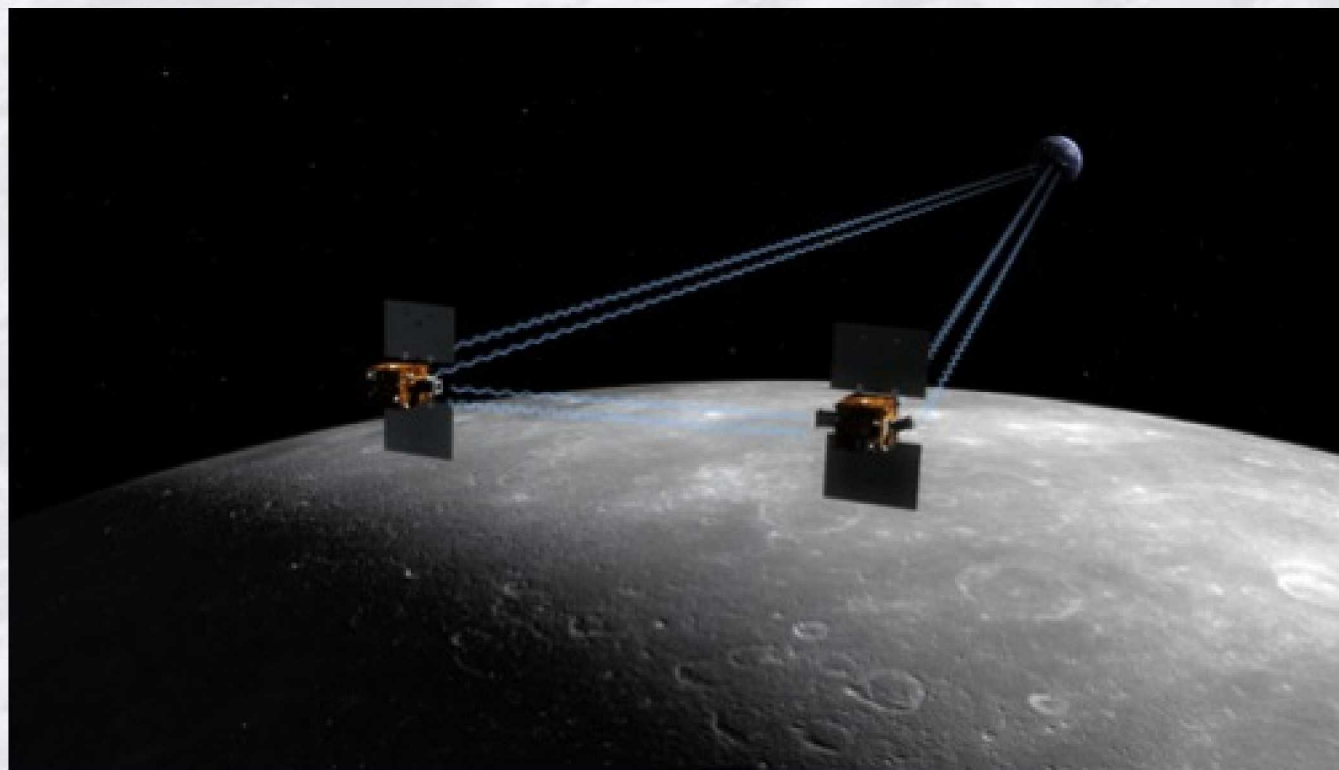
Lunar Quest Program

- ✧ Gravity Recovery and Interior Laboratory - Discovery mission led by Dr. Maria Zuber at MIT
- ✧ Based on GRACE on the Earth - twin spacecraft with mutual microwave ranging to very precisely map the moon's gravity field

## ✧ GRAIL

### Objectives:

- Determine the structure of the lunar interior from the crust to core
- Advance the understanding of the thermal evolution of the moon extending to other planets





# LADEE (2012)

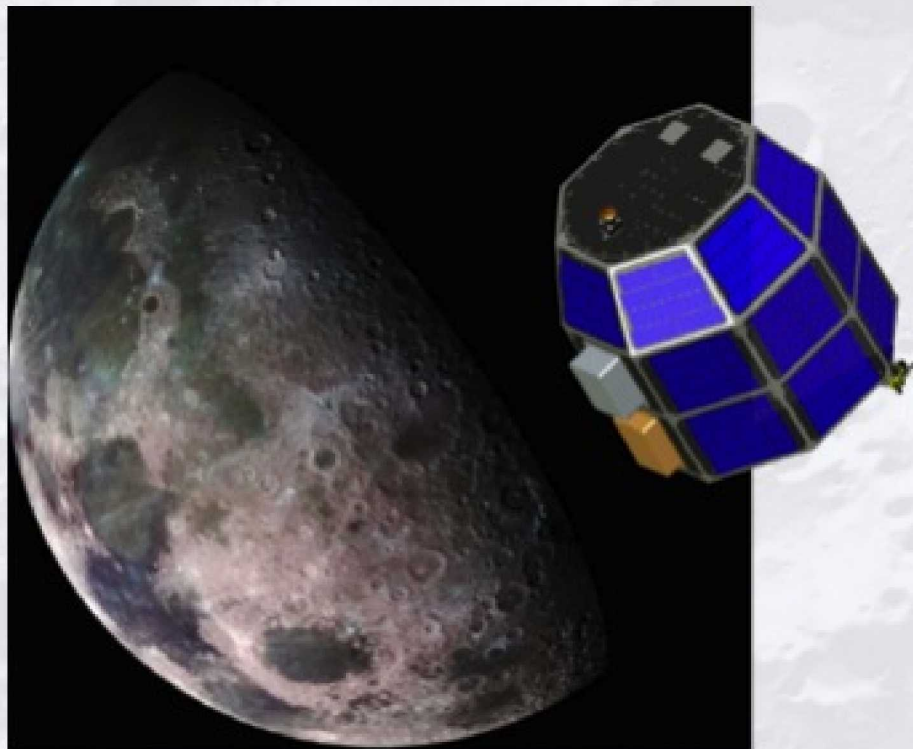


Lunar Quest Program

✧ Lunar Atmosphere, Dust and Environment Explorer - Ames/GSFC project, managed by Lunar Quest Program at MSFC

## ✧ LADEE objectives:

- Determine the global density, composition, and time variability of the fragile lunar atmosphere before it is perturbed by further human activity
- Determine if the Apollo astronaut sightings of diffuse emission at 10s of km above the surface were Na glow or dust
- Document the dust impactor environment (size-frequency) to help guide design engineering for the outpost and also future robotic missions.

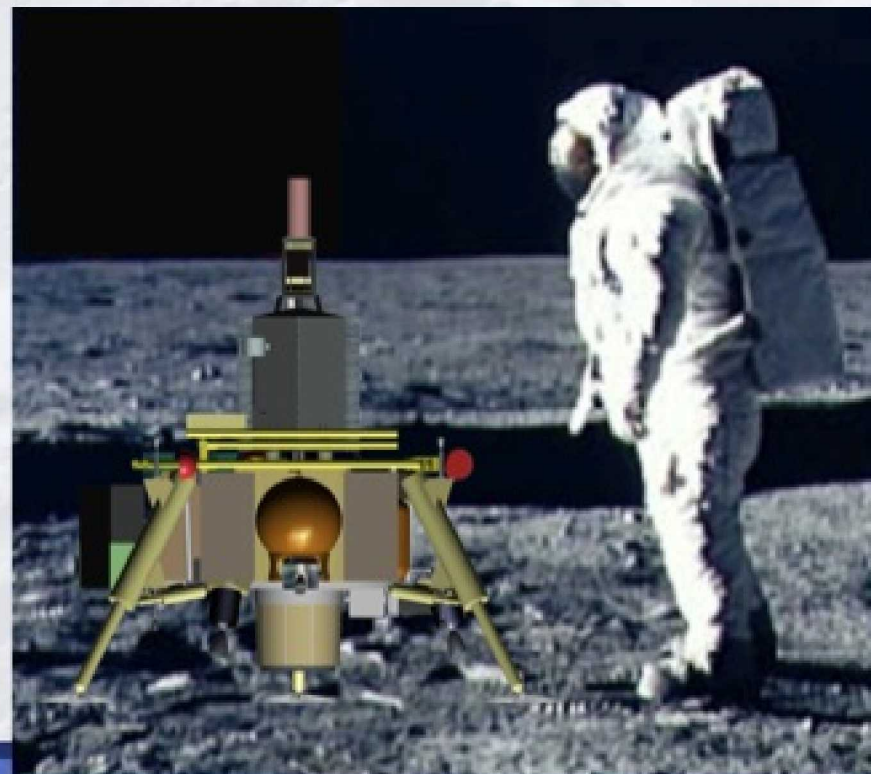


# ILN Anchor Nodes (2016)



*Lunar Quest Program*

- ✧ ILN is a geophysical network that accomplishes high priority science by coordinating landed stations from multiple space agencies
- ✧ ILN Anchor Nodes: 2-4 US landers planned. Project jointly implemented by MSFC/APL, managed by Lunar Quest Program at MSFC





# The ILN and the Anchor Nodes



Lunar Quest Program

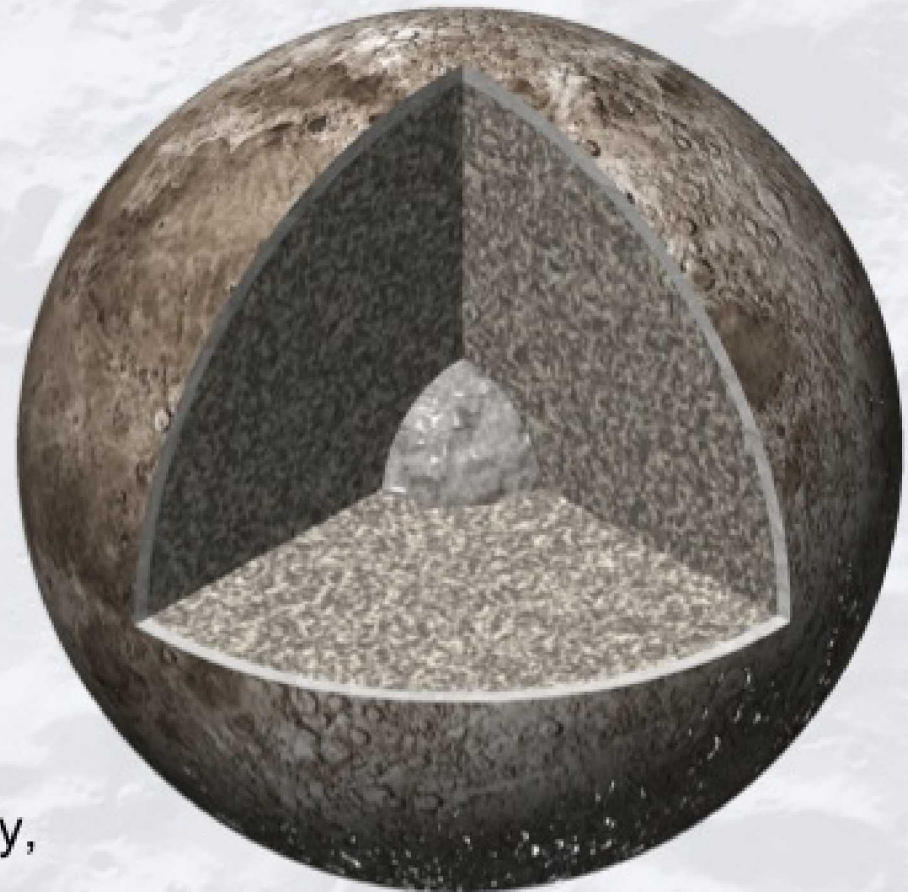
- ❖ A geophysical network is a very demanding mission and the science community acknowledges it would be difficult for a single space agency to accomplish
- ❖ The International Lunar Network (ILN) is an NASA-coordinated effort designed to coordinate international contributions to a geophysical network on the lunar surface.
  - Each ILN station will fly a core set of instruments requiring broad geographical distribution on the Moon, plus additional passive, active, ISRU, or engineering experiments, as desired by each sponsoring space agency.
  - 24 July 2008: ILN Charter Signing Ceremony formed ILN Landing Site, Communications, and Core Instrument Definition Working Groups:  
**Canada, Italy, France, Germany, Japan, Korea, India, UK**
- ❖ The US is currently planning to provide multiple ILN nodes (the Anchor Nodes) through an MSFC/APL partnership – *this mission*.

# A Lunar Geophysical Network



Lunar Quest Program

- ✧ The Moon uniquely preserves a record of early planetary evolution
- ✧ The Moon is a **terrestrial** body – it formed and evolved in a similar manner to Earth, Mars, Mercury, Venus, and large asteroids
- ✧ The Moon is a **differentiated** body, with a layered internal structure (crust, mantle, and core)
- ✧ The Moon is an **active** body, experiencing thousands of deep moonquakes each year, releasing primordial heat, conducting electricity, and wobbling in its orbit



The goal of a Lunar Geophysical Network is to **understand the interior structure and composition of the moon**

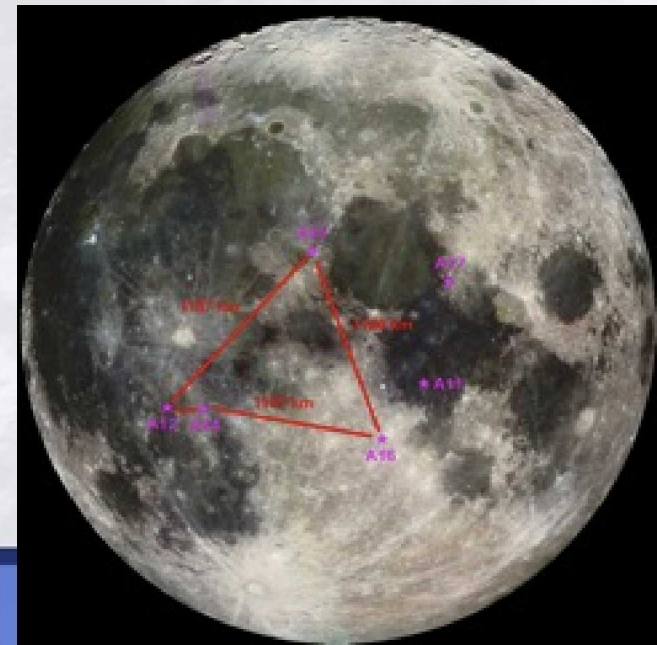


# Anchor Nodes Science Definition Team



Lunar Quest Program

- ✧ A Lunar Geophysical Network has been recommended by the Scientific Context for the Exploration of the Moon (2007), the Tempe meeting (2007), and New Frontiers in the Solar System (2008)
- ✧ To explore this recommendation, NASA HQ convened an independent Science Definition Team to address what science is uniquely enabled by a network. ***Final Report, January 2009***  
[http://lunarscience.arc.nasa.gov/file\\_download/26/ILN+Final+Report.pdf](http://lunarscience.arc.nasa.gov/file_download/26/ILN+Final+Report.pdf)
- ✧ Defined ILN science objectives  $\Rightarrow$  derived mission objectives  $\Rightarrow$  measurement and mission requirements
- ✧ The next generation of geophysical measurements have to improve on our current (largely Apollo-derived) knowledge
  - wider geographical placement
  - more sensitive instrumentation
  - longer baseline of observations



# Science objectives and mission drivers



*Lunar Quest Program*

Objective	Instrument
1. Understand the current seismic state and determine the internal structure of the Moon	Three axis broadband seismometer
2. Measure heat flow to characterize the temperature structure of the lunar interior	Temperature and thermal conductivity measurements to depths > 3 m
3. Use electromagnetic sounding to measure the conductivity structure of the lunar interior	Electromagnetic sounding experiment
4. Determine deep lunar structure by installing next-generation laser ranging capability	Laser ranging experiment



# Science objectives and mission drivers



*Lunar Quest Program*

- ❖ Operations: Seismic stations must operate in concert with one another → simultaneously and continuously operational (day and night)
- ❖ Number of nodes: Need to independently determine the lunar interior composition and structure → 4 nodes
- ❖ Lifetime: Must operate for sufficient time to receive enough signals, span one lunar tidal cycle and exceed the Apollo lifetime → 6 years
- ❖ Location: Must be located >2000 km apart from each other → Strong science desire for farside access to investigate global properties

# Anchor Nodes status and accomplishments



*Lunar Quest Program*

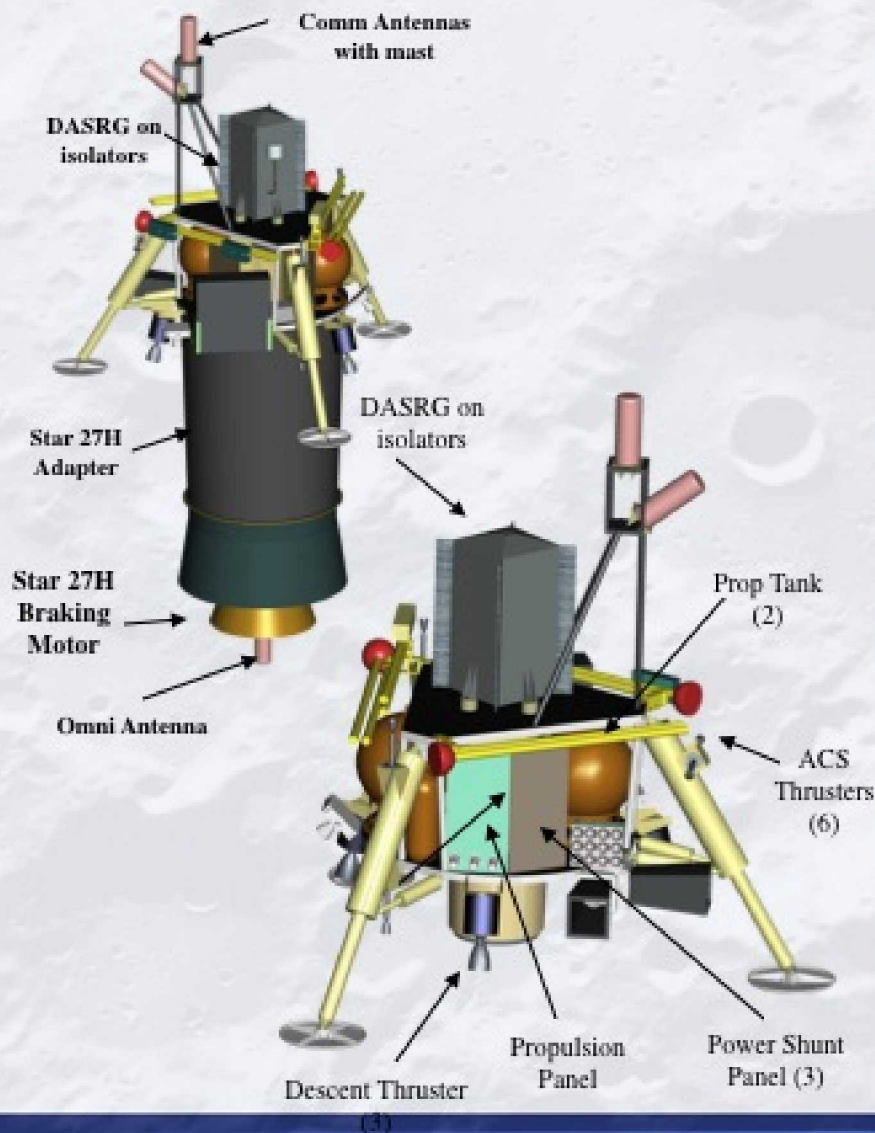
- ✧ Anchor nodes project is in Pre-Phase A
- ✧ MSFC and APL completed and presented eight different mission concept design studies to HQ/SMD
  - Detailed concept engineering analysis and parametric cost estimates were provided.
  - Variations of nuclear powered landers on multiple launch vehicles
  - Variations of solar array/battery powered landers on multiple launch vehicles
  - Phasing of lander launch configurations and dates
- ✧ Project is continuing to work on risk reduction tests and activities to support development of a lunar robotic lander
  - activities for each subsystem
  - MSFC, APL, Ames, JPL, GRC and the local contractor base all providing various tasks
  - Lunar lander testbed



# Baseline Science Lander Summary



Lunar Quest Program








- ❖ Direct trajectory to moon with solid stage providing braking burn.
- ❖ Structure includes composite decks and metal landing legs for soft landing.
- ❖ Liquid bi-propellant landing using high pressure lightweight thrusters and custom tanks.
- ❖ Power provided by Derivative ASRG (DASRG) nuclear power source with small batteries to handle peak power.
- ❖ Daily data transmission to DSN ground station
- ❖ Small warm electronics enclosure with heat pipes & radiator requires no heater power on surface.
- ❖ Landing cameras for horizontal velocity, drives sunlit landing (3-4 day launch window).
- ❖ Single string electronics with parts selected and tested for 8 year life & radiation tolerance.

# Lander Configurations / Launch Vehicles



## Lunar Quest Program

	Minotaur V	Taurus II	Delta II	Falcon 9 B1	Falcon 9 B2	Atlas V 401	Key Lander Risks
	413 kg CCAFS	1250 kg	1285 kg	2000 kg	2680 kg	3580 kg	
 Case 1 DASRG Lander <i>(Floor or Baseline Science)</i>		2 landers	2 landers	2 landers	2 landers (likely 3)	4 landers	- DASRG new development - Propellant tank new development
 Case 2 DASRG Lander <i>(1/2 Floor Science)</i>	1 lander	Case 1 design preferred to accommodate baseline Science for lowest mass lander					- DASRG new development - Mass Margins - Propellant tank new development - Solid Motor new development
 Case 3 DASRG Lander <i>(Floor or Baseline Science)</i>				2 landers	2 landers		- DASRG new development
 Case 4 Battery / Solar Lander <i>(Floor or Baseline Science)</i>					2 landers	2 landers	
 Case 5 Battery / Solar Hard Lander w / penetrator <i>(Floor or Baseline Science)</i>					2 landers	2 landers	- Mass Margins - Air bag new technology - Penetrator performance
Launch Vehicle Risks	- Upgrade of Minotaur V - First launch of Minotaur V Plus Sep 2009 - Requires Yohimbo - Commercial Space Act - Not approved for CCAFS - Not certified for nuclear	- In design - Estimated First Launch Dec 2010 - Not certified for nuclear	- Cost risk associated with maintaining ground facilities	- In design - Estimated First Launch early 2009 - Not certified for nuclear	- In design - Estimated First Launch 2010 - Not certified for nuclear		



# MSFC Lunar Lander Test Bed



Lunar Quest Program

- ✧ Phase 1 – prove out MSFC test facility
  - Ames lent their hover lander
  - Successfully completed 12/17/08
- ✧ Phase 2 – implement MSFC “ILN-Like” test vehicle
  - Cold gas propulsion system
  - Primarily supports demonstration of GN&C algorithms
  - Demonstrations by May 2009
- ✧ Phase 3 – integrate flight-like components for risk reduction tests
  - Landing sensors (cameras, altimeters), Instruments, Structure features (legs)
  - Alternative prop systems for descent and landing tests



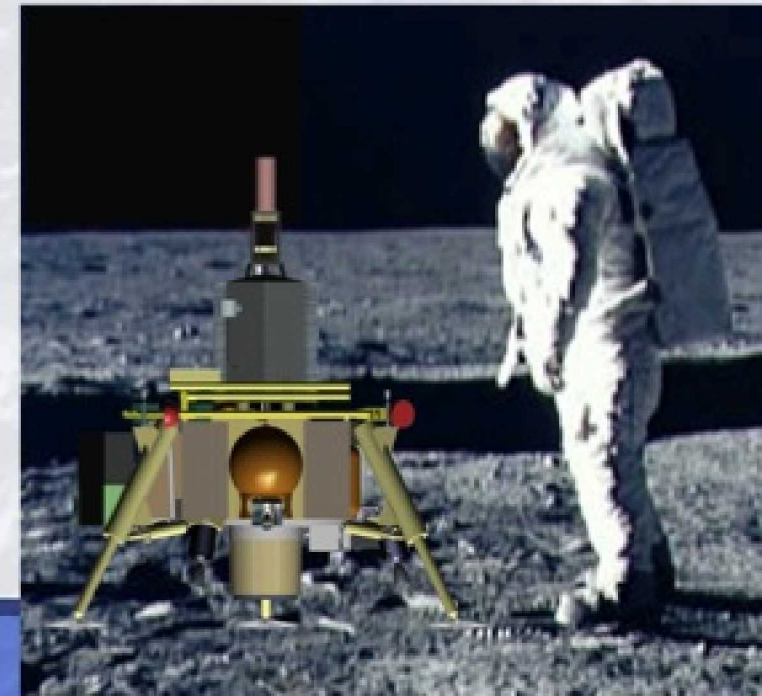


# Summary



Lunar Quest Program

- ✧ The Lunar and Planetary Science group at Marshall provides core capabilities to support the Agency's lunar exploration goals
- ✧ ILN Anchor Nodes are currently in development by MSFC and APL under the Lunar Quest Program at MSFC
- ✧ The Science Objectives of the network are to ***understand the interior structure and composition of the moon***
- ✧ Pre-phase A engineering assessments are complete, showing a design that can achieve the science requirements, either on their own (if 4 launched) or in concert with international partners
- ✧ Risk reduction activities are ongoing





# Backup



Lunar Quest Program

## ✧ ILN Project Organization



# ILN Anchor Nodes Project Organization



Lunar Quest Program

